UNIVERSITY OF CALIFORNIA
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AUSTRALIAN SALT-BUSHES

Results of Eighteen Years' Tests: Characteristics, Propagation, and Field Experiments

By CHARLES H. SHINN

Composition and Food Value

By M. E. JAFFA

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Plate 1.—RHAGODIA SPINISCENS INERMIS.

AUSTRALIAN SALT-BUSHES.

RESULTS OF EIGHTEEN YEARS' TESTS: CHARACTERISTICS, PROPAGATION, AND FIELD EXPERIMENTS.

By Charles H. Shinn.

The story of the introduction of various species of Australian salt-bush, of the tests made at many places and on a great variety of soils, of the difficulties encountered, and of the ultimate proof of the great value of some species to California, is both interesting and instructive. It serves to show that much time and patience are requisite in work of this kind, and it should also encourage local experimenters to renewed efforts.

The Australian salt-bushes seem to have been first mentioned in the Report of the College of Agriculture for 1882. Dr. H. Behr, of San Francisco, had long advocated the trial of the Australian atriplexes, and in June, 1881, through his correspondence with the late Baron Von Mueller, seeds of two species, *A. vesicaria* and *A. nummularia*, were obtained and sent to the University for propagation.

The first seeds obtained were badly mixed, and it took some time to determine the species, since herbarium specimens were lacking. But Baron Von Mueller, having begun to supply California with these valuable plants, continued to send seeds every year as long as he lived; these included new species as fast as they were obtained from the deserts, and, through specimens of plants, and his publications, aided in identifying those previously sent.

In the spring of 1882, the late Mr. W. G. Klee sent plants of two atriplexes, one a tall species, *A. nummularia*, to the salt marshes near Alvarado, where they were planted on the lands of Mr. G. Schoof. *A. nummularia* grew very well indeed, was propagated with ease from cuttings, and throve "in decidedly alkaline lands where hardly anything but Samphire *(Salicornia)* would grow." Mr. Klee wrote (Report of 1882): "The relish with which cows eat every particle of it would seem to make it a pasture plant worthy of extensive culture."

First Distribution and Results.—In Bulletin No. 2 of the Agricultural College, under date of January 15, 1883, *A. nummularia* was first offered—ten plants to each applicant. This is the species of which Baron Von Mueller says: "One of the tallest and most fattening and wholesome of Australian pastoral salt-bushes, also highly recommended for artificial rearing." Even in 1879, when this was

written, the more valuable species of atriplex were rapidly disappearing over wide areas of Australia.

In a "Report on Grasses, Forage Plants, and Cereals," made in 1886, by Professor E. J. Wickson, a number of letters were printed from those who received *A. nummularia* for trial. Four farmers reported that horses, cattle, and sheep were fond of the plant, and that it was a decided acquisition. Two farmers reported that animals would not eat it. Mr. S. G. Baker, of Norwalk, Los Angeles County, wrote that this atriplex grew "in soil containing thirty per cent of salt, but it died in soil containing sixty-five per cent of salt and eleven per cent of soda." This probably refers to the alkali crust, certainly not to the mass of the soil. On the whole, the Department, in 1886, considered *A. nummularia* more useful than any other species, although by that time *A. halimoides* and *A. vesicaria* were also being grown.

In 1888, Baron Von Mueller sent seed of *Atriplex semibaccata*, with the remark that it might fill some place in California, but was quite small, and not so desirable as the tall salt-bushes such as nummularia. He also sent two species of *Kochia*, which, so far, seem to propagate too slowly to have much practical value, although they are still in the economic garden with various atriplexes and other salt-bushes.

Salt-Bushes Planted at Tulare.—The same year (1888) one species of *Kochia* and several other salt-bushes, including *A. semibaccata*, were planted at the newly-established sub-station near Tulare. Mr. Julius Forrer, foreman of this sub-station since its establishment, saved seed of *Atriplex semibaccata* in 1889, and sowed it as a border to some of the roads. Since the ground was very "spotty," having different degrees of saline strength, this soon showed roughly the alkali-tolerance of the plant, and it was found to be extremely high. Mr. Forrer continued to sow seeds in test plots on other parts of the tract, and made local tests in the district. In the autumn of 1890 he called the attention of the inspector to the value of *Atriplex semibaccata*, declaring that it was much the best of the salt-bushes, as it could be handled like alfalfa on account of its numerous thin, flexible stems, while most of the others were suitable only for browsing.

Tests of this atriplex were continued at Tulare from 1890 to 1894. Little was published by the California Station concerning it, but it received much local attention, and by 1894 several farmers had planted fields of considerable extent. By that time seeds had been distributed to many persons in Tulare County; plants of twelve and even sixteen feet in circumference, grown in a single season on strong alkali spots, had been exhibited in the offices of local newspapers, and at county and district fairs. It was found that chickens, hogs, sheep, goats, cattle, and horses throve on the plant. It was often somewhat difficult to induce work-horses or milch-cows, accustomed to hay and alfalfa, to accept the new fodder, but on the whole, the results obtained appeared to promise a wide usefulness for the salt-bush.

Investigation of Food Values.—In 1894, the Station published the results of analysis of the salt-bush compared with those of some other green fodders, which showed the amounts of digestible nutrients to be very considerable, comparing well with alfalfa. As tabulated with later analyses, these investigations, made by Professor M. E. Jaffa, appear elsewhere in this Bulletin.

Station and Farm Experiments.

After *Atriplex semibaccata* had been thoroughly tested in plots at Tulare sub-station, a carload of volunteer plants was (1894) given to the Kern County Land Company, who planted about forty acres in one field and many small plots in different locations. The plants throve everywhere and were reported to be a great acquisition, (see letter of A. B. Leckenby, Annual Report of 1894-95, page 321.) Some individual plants attained a diameter of eighteen feet in one year. The main field was partly pastured, partly used to secure seed, and a large crop was gathered and sold at considerable profit. The tract was then irrigated and partly sown to alfalfa. A great deal of the salt-bush remained when the place was visited in 1898, and improved the pasture. Other and larger plantations of salt-bush have since been made on more arid ground.

Mr. Turner, of Tulare, planted a large pasture about the same time, which still remains in use. Mr. Welch, of East Oakland, planted about 50 acres in the same county, and like Mr. Turner has found it profitable for pasture. Neither of these gentlemen irrigated at all.

In February 1896, the Tulare sub-station, needing more land, secured the use of six acres of unproductive alkali soil, on which to make a field test. Salt-bush seed was drilled here on the surface, in rows eight feet apart, and by September, when visited, the surface was nearly covered. A part of the crop was cut twice, yielding at the rate of four tons of hay per acre; the rest being allowed to ripen seed for distribution and exchange, was cut late and stacked for feeding to sheep. The surplus not required by the station was given to farmers, who hauled it home, fed it to cattle, and reported that it was excellent. A large irrigation ditch broke in 1897, flooding the low basin of this field, and destroying most of the salt-bush, thus preventing another season's results and emphasizing the evil of giving too much moisture to this desert plant.

Successful field-tests in tracts of five acres and upwards have been reported from Bishop, Inyo County; from Byron, Contra Costa County; Wilmington and many other places in Los Angeles County; Arbuckle and Colusa, in Colusa County; Bakersfield, Kern County; Traver, Kingsburg, Visalia, Tulare, and Goshen in the upper San Joaquin Valley.

Salt-Bush on Non-Alkali Uplands.—Mr. A. V. Stubenrauch, then foreman of the Paso Robles sub-station, sowed seed of *A. semibaccata* in April, 1896, in boxes, transplanting them to the open ground the first week in June. About 100 plants were thus established, some under a large oak, others close to the county road. By November 10 each plant was a mass of growth three feet in diameter. The following winter hundreds of volunteer plants sprang up, and both seeds and plants were freely distributed in the district. Late in the spring of 1898, Mr. Sedgwick, then foreman, sowed *A. halimoides*, *A. vesicaria*, and *A. hortensis* as well as a larger area of *A semibaccata*. The season was so dry that the results were extremely instructive.

Drought Endurance.—The total rainfall at the Paso Robles station for the season of 1897–98 was but 3.24 inches, to March; April and

May showers brought this to 4.75. The season was marked by very strong "northers." None of the native spring bulbs, such as Calochorti, Brodiæas, etc., bloomed, and few even made leaves. By the first of April, the roadsides were brown and barren. On unirrigated land there was no green fodder-plant excepting salt-bush, in the entire region.

The growth of *A. semibaccata* on this poor and arid soil was a revelation to every farmer. Seed sown in December 1897, made a foot of growth by April 12th, branching and covering the ground. After being cut back for sheep feed, it made a second growth of six inches by the end of May, and was cut a third time before the end of the summer. All that was sown in December, as well as the plants that were two years of age, throve without irrigation and found the small rainfall of less than five inches sufficient. In fact, two-year-old plants which were in rows two feet apart, covered the ground and yielded a large crop of seed.

One-fifth of an acre, sown in December yielded 100 lbs. of seed. This plot was cut in September and, cured for fodder, yielded at the rate of five and one-half tons of hay per acre. Three such cuttings were practicable on this light, granitic, sandy loam, underlaid by hardpan, during the driest season known.

The January and February sowings of salt-bush nearly failed, and on April 12th, 1898, were dying. The average plants were then from one to two inches high, with single roots descending two to three inches deep in the dry soil, which since sowing had received less than three and a half inches of rain, and no cultivation. These plots were given, by measurement, water equivalent to one inch of rain and were then thinned and hoed. On May 28th the average plants were eight to nine inches high—some twelve inches—and all were many-branched, showing from six to fifteen succulent growths from each crown. The roots had penetrated from ten to eighteen inches. No more irrigation or cultivation was required.

Reports of Field Tests by Correspondents.—Out of the numerous letters received regarding the value of the salt-bush, a few are given here to show the range of the plant.

From the west side of the Sacramento Valley, at Arbuckle, Colusa County, under date of December 26, 1898, W. C. Bradford writes: "The salt-bush grew from a few inches to three feet in diameter on hard, dry clay land where even weeds did not grow; and it volunteered from self-sown seeds in the hard road and walk, growing slowly all summer." Jasper Kolpien, of Grimes, also in Colusa County, writes: "Grows well here, and about every farmer is growing some this year, as a good many tried it last year, and all praise it." J. Lewis, of Maxwell, Colusa County, and others in the same district say: "The salt-bush will be the salvation of the 'goose lands'" (hard clay soil, with white alkali.)

Success in the Sierra foothills is reported by W. C. Cockrill, of Latrobe, El Dorado County. In December, 1898, he wrote: "It does well in this locality. I planted it in boxes, and transplanted it in April on very dry ground. It made a growth of about two feet without any irrigation. In August the cattle broke in and ate it all off,

but it commenced to grow again, and remained green all fall, and is green yet." Thus far no alkali has been found here.

Many excellent reports come from the alkali districts of Honey Lake and other valleys of Lassen County. A typical letter is from Tully DuVall, of Datura, Lassen County, written in February, 1899. He says: "Australian salt-bush sowed June 1, sprouted June 11; then spread two feet in diameter. From one plant I gathered a quart of seed. Though sowed so late, it stood the frost better than alfalfa. In October it was still green, when the alfalfa had withered away. It stood the severe winter of 1897–98 and is now growing. The soil was alkali."

From many places in the San Joaquin Valley and its adjacent foothills favorable accounts have been received. Many such were printed by Professor E. J. Wickson in recent annual reports. Mr. G. F. Donkin, of Grayson, Stanislaus County, writes in December, 1898: "I only succeeded in growing one plant in 1897; which spread out six feet and seeded heavily. In 1898, a great number of young plants came up around the old one, and I furnished plants to my neighbors, besides planting 125 small ones in the field. They are a success; and my chickens, turkeys, horses, and cows all like it. Turkeys invariably go to the salt-bushes. A cattle-raiser here told me it is excellent feed for cattle, and he intends to grow some on the hillsides."

Experiments with salt-bush in the Coast Ranges have not been so numerous as in the San Joaquin Valley, but promise equally satisfactory results. In December, 1898, Mr. T. E. Rice, of Livermore, Alameda County, wrote: "I have grown the Australian salt-bush *(A. semibaccata)* for two years, and am well pleased with it. It seems to stand the drought better than either of the others. Mealy salt-bush *(A. halimoides)* grew about two feet high, but does not make nearly as much feed as the other. No. 2 *(A. leptocarpa)* was just about a failure." Miss A. E. Howard, Pozo, San Luis Obispo County, wrote that it kept green all summer, and "furnished excellent feed December 15th." Similar reports came from Creston, Paso Robles, San Miguel, and Shandon. Mr. A. M. Hardie, of Cayucos, near the coast of San Luis Obispo, praises it highly in a report made in May, 1899.

An excellent report of salt-bush planting on non-alkali soil comes from Mr. G. E. Heaton, of San Luis Obispo County, whose farm is in the Santa Lucia Range, west of Paso Robles. He writes that his soil is heavy and dark, with considerable adobe, no hardpan, elevation about 1,500 feet above the sea, exposure eastern, sloping 15 feet to the hundred; there is timber on top of the hill, and the land is shaded after 4 o'clock P.M. He continues: "The rainfall for the season of 1897–98 was five inches, of which about one inch fell early and was dissipated before the seed was planted; most of it fell in February and March. The yield of salt-bush was approximately thirty tons of green forage per acre, though badly injured by a neighbor's cattle in August. It is relished by stock. I have only tried horses; some eat it at first sight, in preference to good wheat-hay, others require coaxing, but after once eating it seem to relish it. Cattle that broke into the field ate the salt-bush as greedily as beets that were planted alongside. Young plants this season (January, 1899) resisted, without injury, frosts that killed young cabbage plants in the same situation. Old

plants take on a dingy look during the continued frost, but start a new growth as soon as the weather moderates. It endures cutting and cropping better than alfalfa, not dying back like that plant, but starting again all along the stem and from the crown also."

Domestic Animals will eat Salt-Bush.—Some correspondents have reported that they could not persuade livestock to eat salt-bush (*A. semibaccata*), "notwithstanding the favorable analysis," as one farmer wrote. By taking all the letters received during four years at the Station, which touch directly on this point, and tabulating them, the following results are obtained:

Five farmers say, "Nothing will touch it; stock won't eat it; it is a failure on this account." All these farmers admit that it grows well. One of them does not seem to have had salt-bush, but to have been testing something else, by mistake.

Eight farmers say, "Stock will eat a little," or, "Only when dry."

Thirty-seven farmers say, "Stock thrive upon salt-bush, are very fond of it." Cattle, horses, sheep, goats, and poultry are included in the lists given.

Many other correspondents who do not mention this particular point at all, speak of extending their acreage of salt-bush, and therefore it may be presumed that they have found the food-value satisfactory.

At Tulare sub-station salt-bush was fed to sheep, cattle, horses, and hogs. With the sheep, the ration was increased until some received nearly their whole sustenance for months at a time from this plant, keeping in excellent condition, and being turned off to the butcher as "fat mutton" without any other food except a little straw.

Still, there must be a reasonable foundation for some of the difficulties that farmers have experienced in feeding salt-bushes. In fact, salt-bushes probably vary in edibility at different seasons of the year on alkali soil. All the available evidence goes to show that only a small proportion of the many species of salt-bushes of the world are really acceptable to live stock. *Kochia pyramidata*, as reported by Mr. J. H. Maiden, contains thirty-seven per cent of uneatable material. *K. aphylla* is so fibrous that it forms bezoars in the stomachs of sheep, and often kills them. Some of the atriplexes are seldom touched except in times of great necessity.

Vegetative Characteristics of the Salt-Bushes.

Tolerance of Alkali.—The studies of alkali soils made at different times at Tulare sub-station by Director Hilgard, Professor Loughridge, and other members of the Station staff, have shown that the resistance of salt-bush to the effects of alkali is very satisfactory. There is, of course, a limit to such resistance. Some correspondents report that they planted it in black-alkali crust, and were disappointed at its failure. One farmer says: "The alkali destroyed, or ate off, the stems of the salt-bush; it did not seem to get a start at all." Expectations of success in such places cannot, of course, be realized. On land of which the surface foot contains one-third of one per cent. of salt, the young plant was found to come up easily, but suffered when the salt contents reached nearly eight-tenths of one per cent.,

or about 31,000 pounds of salts to the upper acre-foot. Some of the older plants lived well in soils having a total of 92,000 pounds per acre in a depth of three feet, of which 23,000 pounds was "black alkali." Where the surface crust, or upper half-inch contained eight per cent. of salts, the young plants barely kept alive, and when the amount of salts near the surface was twenty-five per cent., they perished. Nevertheless, there are cases at the Tulare sub-station, where single plants, under favoring circumstances obtain root and thrive where the amount of alkali approaches these highest limits. Certainly no other useful plant so sturdily withstands "black alkali." Barley for instance does not make a crop on land containing over 30,000 pounds of total salts per acre.

Since 1894 the continued experience of several hundred farmers in the San Joaquin Valley has emphasized the same points, showing that *Atriplex semibaccata* is the best species yet tested for alkali soils in regions of hot, dry summers and light rainfall. Though in such districts it responds readily to irrigation, it seems to be easily "drowned out" or rotted by too much water. It thrives on the banks of irrigation ditches, and aids to bind the soil, forming, where pastured closely, a compact covering. It is now well established along the highway near the sub-station, and volunteers freely. It has been successfully started on hard, unplowed pastures and roadsides.

Salt-bushes grow extremely well on the ten-acre tract near Chino, which forms part of the Southern California sub-station. There they are planted in seven different plots, to test resistance to alkali in this district. The amounts of alkali in the soil range from a total salt-percentage of .067, or 2,680 pounds, to about 7,080 pounds per acre. The limit of endurance has not been nearly reached in this case, and the plant can be recommended for all places in this region where beets and alfalfa fail on account of surplus alkali salts. The species planted were *A. semibaccata* and *A. leptocarpa*. Both do extremely well.

Resistance to Frost.—Most of the alkali lands of California, being in the lowlands, are subject to heavy winter-frosts. However, "salt-bush withstood more frost than alfalfa" at Bishop, Inyo County, and at Datura, Lassen County. It grew fairly well in Weber County, Utah; at Oroville, State of Washington; in Mills County, Oklahoma; at Clarks, Nebraska, and at various places in Texas and New Mexico. The plant remains green very late in the season—a strong point for stockmen. At Bishop, Inyo County, it was green, in bloom, and with seeds in all stages, on November 23rd. At Biggs, and also at Colusa, the leaves were still green in December. At Latrobe, El Dorado County, it was green and growing December 22nd. The top certainly withstands a temperature of 14° Fahr., but how much less has not yet been determined.

Root System and Penetration.—So far as observed by studying the root-system of the plants grown at Tulare sub-station, where water is abundant at less than twenty feet, the salt-bush does not need to go deeper than five feet. Even in the dryest seasons, when grain crops cannot find sufficient moisture, and perish, the salt-bush thrives, making heavy growth. The following photograph clearly illustrates the root-system of a typical alkali-soil specimen, from Tulare sub-station, taken by Professor Loughridge, illustrates the manner in

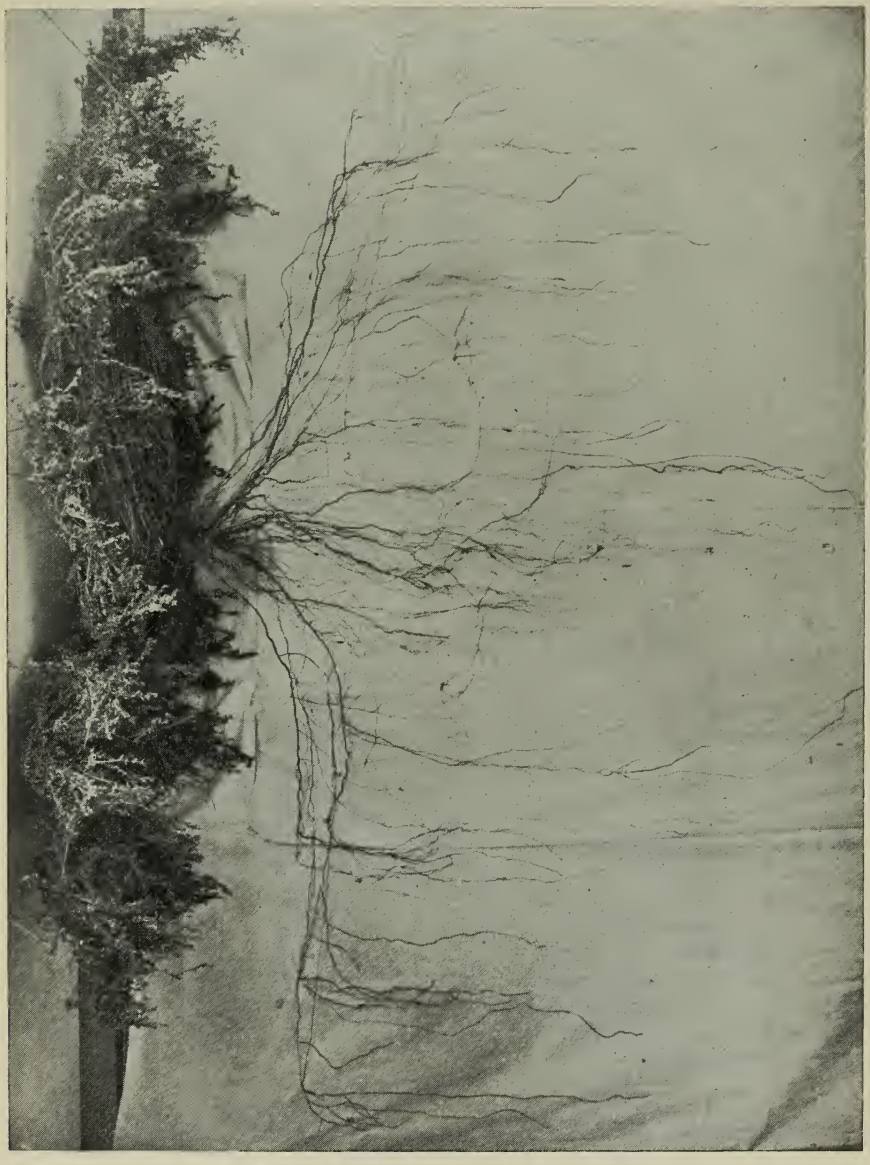

Plate 2.—Root System of Atriplex semibaccata in Alkali Soil.

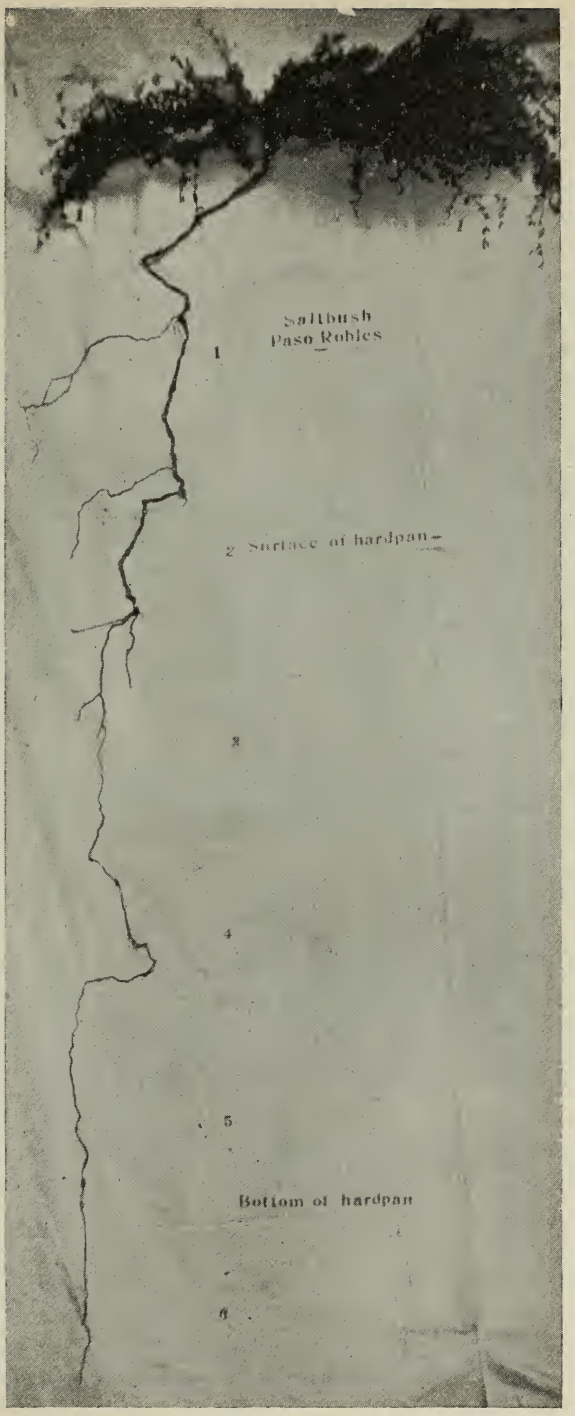

Plate 3.—Root System of Atriplex semibaccata in an Upland Soil.

which it grows. This should be compared with the surprisingly different root-system of the salt-bush in Paso Robles on non-alkali and non-irrigated upland, which is shown in Plate 3.

This Paso Robles salt-bush plant, two years old, was taken up in the fall of 1898, when green and growing, and the position of its roots studied and mapped. The main root bored its way downward until the streak of moister soil just below the hardpan was reached, when the plant, which had remained green all the time, gained new energy. The main root was nearly an inch in diameter at the surface of the ground; at the point where it finally broke off and could be traced no farther downward, it was the merest thread.

Growth on Soil Underlaid by Hardpan.—But the most important discovery from this experiment at Paso Robles was that the salt-bush grew well on a soil that was not only dry and uncultivated, but was also underlaid by hardpan. Many borings over the tract have determined the depth of surface soil, and in many places also the thickness of the underlying hardpan. Plants have only from one to two feet of open soil in which to grow before they find a hardpan of from twenty inches to six feet in thickness through which the roots of but few species of plants can penetrate. The native oaks, the English oak, mulberries, and locusts do indeed slowly extend through it, but apricots, peaches, cherries, and most orchard trees merely spread out their roots on its surface for some years, then cease to grow, and finally die. When wet by rain, this hardpan becomes easy of penetration, a fact of which the salt-bush takes advantage, starting growth as it does, with the first autumn showers.

Moisture in Saline-Soils.—The amount of moisture in the soils in which salt-bush maintained its growth at Tulare and at Paso Robles in 1898, has been determined by Professor R. H. Loughridge in the course of his extensive studies in this line, and is shown in the following table:

Soil—Moisture Tests: Summer of 1898.

Depth at which Taken.	Tulare.				Paso Robles.	
	Sandy Soil.		Strong Alkali Soil.		Hardpan Soil.	
	Per Cent.	Tons Per Acre.	Per Cent.	Tons Per Acre.	Per Cent.	Tons Per Acre
1 ft.	0.8	16	15.9	318	0.9	18
2 ft.	2.9	58	8.5	170	2.8	56
3 ft.	9.5	190	15.5	310	3.3	66
4 ft.	6.5	130	15.1	302	12.2	244
5 ft.	—	—	17.0	340	7.8	156
6 ft.	—	—	—	—	7.5	150
Total	4.9	394	14.4	1440	5.8	690
	Rainfall for season, 4.33 inches.				4.75 inches.	
	Depth to water, 13.5 feet.				150 feet.	

The point most striking in the foregoing table is the wide difference between the moisture contents of the sandy land and strong alkali land at Tulare, being nearly ten per cent. in favor of the latter. This illustrates one of the points which doubtless influences the preference of the salt-bushes for alkali soils, and their vigorous development where other plants would utterly fail to maintain themselves. Evidently they are able to share the moisture absorbed by the hygroscopic alkali salts, even when the latter are present in large proportion. It has long been known that grain can be grown successfully without irrigation on lands containing a very small proportion of alkali salts, while soils alongside, but free from the latter, produce no crop; as is also the case in stronger alkali lands. The wide limit of adaptation tolerated by the salt-bush is strikingly expressed in the figures showing the amount of water per acre in the second column of each group; at the same time, it would doubtless have been found that in the case of the sandy land the roots penetrated to much greater depths than in the alkali soil; the same is true in the case of the Paso Robles sandy soil, whose moisture content was only half that of the alkali land of Tulare. Another striking fact is the amount of water held below the hardpan, as shown in the Paso Robles column.

Leaf-Habits.—The leaves of *A. semibaccata* in the alkali districts remain nearly flat; but at Paso Robles, upon the light, dry soils of the district, the leaves fold inward more or less closely during the heat of the day, and open out at night. No other salt-bush showed this feature to any appreciable extent. *A. halimoides*, one of the best of the upright species, does well at Paso Robles, and so does *A. leptocarpa*, a trailing species. Neither of these, however, make nearly as much growth as does semibaccata, whose leaves have been seen, under a dry norther in July or August, folded as closly as those of a rudely-touched sensitive plant.

Propagation of Salt-bushes—The Seed Industry in California.

Many salt-bushes can be propagated from cuttings, but the cheapest and best method is from seed. These can be sown in boxes and transplanted to the desired fields where they easily root and soon, from self-sown seedlings of subsequent seasons, cover the entire ground. More vigorous plants and a better root-system are obtained by sowing where the stand is desired.

Utility of Transplanting.—It is often desirable, however, to transplant seedlings. They may then be set in rows four feet apart on light or hardpan soils and six to eight feet apart on alkali soils. The plants may stand from one to four feet apart in the rows. The seedlings should be well hardened, and three or four inches high. The tops should be pinched back, taking off two-thirds of the growth; they are treated like young cabbage or tomato plants, firming the soil about the roots. A great many correspondents have followed this method with success, and thus have utilized every seed obtained. The salt-bush transplants easily. At Paso Robles, on March 3rd, 1898, one hundred plants were taken from seed boxes, pinched back, set out, watered once and shaded for forty-eight hours. The test was a hard

one, as all of the soil was purposely shaken from the roots, and at the end of forty-eight hours, the plants were exposed to the full sun-light; but eighty-five per cent grew and throve. The individual salt-bush which penetrated the hardpan and is illustrated above (plate 3), was a transplanted specimen.

Seed-Sowing Preferable. — The vast majority of planters will naturally prefer to sow seed. There is no difficulty in securing a good and uniform stand if the following directions are carefully considered and modified to suit local conditions. The primary rule to remember is that these salt-bushes are plants of the desert. Their seeds start easily and rapidly, with little moisture and little or no covering, but the soil must be *warm*. This means, in California, early sowing with the first warm autumn showers. But details of treatment differ radically on alkali soils and on arid uplands, and these differences are worth noting here.

Seed-Sowing on Alkali Soils.—Almost without exception, farmers who have attempted to cover salt-bush seed on alkali soils have found that it rotted in the ground. They should sow with the first rains on well-prepared soil. "Firm" the seed into the soil—that is, press it down so that the roots can start better; but do not cover it. Self-sown seeds start by thousands on the surface of the soil, or even on hard roadsides, in the Tulare district. This is usually in October, and these seedlings endure frosts of 17° Fahr. by December without injury. By March, such plants are far ahead of transplanted stock.

If the October sowing-time is lost, planters must sow in boxes, or wait till the cold rains are past and the soil gets warmer. Such late-sown plants can not produce, the first season, nearly so large a crop either in forage or in seed as do those sown in October.

In brief, the points for sowing salt-bush on alkali soil in warm districts are: Sow early, on the surface; press into the soil but do not cover; protect from birds, which are very fond of the seeds.

Seed-Sowing on Arid Uplands.—At Paso Robles and throughout the Coast Range and Sierra foothills generally, on hardpan, light, and arid soils, the best experience is that a slight covering is advisable. Another letter from Mr. Heaton, of the Santa Lucia foothill region, is worth quoting in this connection. Under date of April 5, 1899, he writes: "I have had no success with seeds sown on the surface. My seed was sown the middle of February, in drills six feet apart. The land was prepared as for carrots; seed was covered from a half to one inch, and the soil firmly tramped on by foot. My soil dried out very quickly, superficially, but conserves moisture well below. Plants were hoed twice and kept free from weeds. No other cultivation was given."

Germination Tests.—Tests of three-year-old seed were made, in 1897, by Mr. H. G. Wright, at the Central Station greenhouses, and the results plainly showed the advantage of slightly covering in non-alkali soils. The seed was sown August 6th, in seed-boxes, under glass; soil moist, but not again watered.

In the following table are shown results of germination tests, which seem to show that a covering in ordinary non-alkali soils is an advantage, but it must evidently be slight:

Results of Germination Tests.

Soil Covering.	Date of Germination.	Percentage of Healthy Plants.
$\frac{1}{8}$-inch	August 9th	70 per cent.
$\frac{1}{4}$-inch	August 10th	50 per cent.
$\frac{3}{8}$-inch	August 11th	45 per cent.
$\frac{1}{2}$-inch	August 12th	25 per cent.
Not covered	August 16th	30 per cent.

Another test, respecting the amount of moisture best applied, showed that seed sown on the surface, and watered every day, germinated seventy-five per cent.; seed similarly sown, but watered every third day, germinated eighty-eight per cent.; seed that was not watered until the fifth day, failed to germinate.

THE SEED INDUSTRY.

Salt-bush seed is not cheap, even in the markets of Australia, for the gathering and cleaning is expensive. In 1889–91, when Baron Von Mueller was sending so many packets to the California station, Australian prices ranged from four to six dollars per pound. About 1895, when the value of *Atriplex semibaccata* to California became known, enterprising seedsmen began to offer it. Up to the present time sale has been found for a great deal of seed, although no statistics are obtainable, and prices have been so well maintained that it is believed there is still profit for both dealers and growers.

There is a great deal of difference in size, color, and quality of seed grown in various districts. Seed is easily overheated, blackened in the sun, or spoiled by dews. It is hard also to obtain seed free from admixture of light weed-seeds. The percentage of germination has varied in samples sent to the station from less than twenty to nearly ninety. Anything below seventy-five per cent. is certainly very poor seed. The bulk of the seed gathered by farmers will of course be used to sow again, as few are prepared to thoroughly care for seed and prepare it for market. Salt-bush pasturage on arid and on alkali land is what is chiefly needed, and surplus seed must find its market for planting on these soils.

The brightest-colored and heaviest seed has so far come from unirrigated alkali soils having a rainfall of from six to ten inches, and sufficiently removed from the influence of coast fogs and winds. Seed of a slightly less bright color, from ten to fifteen per cent. smaller, but germinating nearly or quite as well, has been grown on the arid foothills of Monterey, Kern, and San Luis Obispo (east ot the Coast Range summits). Seed grown at the Santa Monica sub-station, near the ocean, on sandy soil, was small and poor. Seed grown at the sub-station near Pomona in Southern California was dark in color, light in weight, and did not germinate well. Seed grown at Amador foothill sub-station, receiving some irrigation, was small and dark, but that growing on a slate hillside, unirrigated, was much better in quality. Seed has been received at the Experiment Station from twenty-one farmers in nine counties, and plants have been examined

at many other locations besides those mentioned above, the conclusion being, as stated, that unirrigated alkali soils, in a region of light rainfall, will produce much the best market-crop of seed.

1 2 3 4

Plate. 4.—Seeds of Australian Salt-bushes.

1. A. semibaccata. 2. A. vesicaria. 3. A. leptocarpa. 4. A. halimoides.

Seed Distribution.—Returning to the history of the work done with this atriplex by the California Experiment Station, its various seed distributions deserve notice. These really began in 1889–90, on a limited scale, following the still earlier distributions of *A. nummularia*. In December, 1894, the station felt justified in much broader experiments, and accordingly announced a general distribution. This has been continued until now, and in the five years, about 1,500 pounds of seed have been disseminated throughout California in small trial packages, at a merely nominal price to cover packing and postage. During eight years (1891–98 inclusive) about two thousand pounds of salt-bush seed were distributed in trial packages, without charge, from the Tulare sub-station or by local newspapers of the San Joaquin Valley. A large amount of the seed was also required for exchanges in this country and Europe. The total salt-bush seed-crop of the Tulare sub-station since 1891 has been not far from 5,000 pounds.

The accompanying illustration (Plate 4) shows seeds of the leading species natural size, now grown in California.

Salt-Bushes in other Countries.

with notes on some pacific coast salsolaceæ.

The great Goosefoot family of plants *(Salsolaceæ)* has deservedly received the attention of many investigators. Perhaps the best technical arrangement of Australian species is that of Mr. Bentham's "*Flora Australiensis*." While all botanical writers who allude to salt-bushes note their surprising capacity of resistance to alkaline salts,

especially of carbonate of soda, the principal authorities, from an economic stand-point, have been the late Baron Ferdinand Von Mueller, Professor F. Turner, and J. H. Maiden, in Australia, and Professor McOwan, of Cape Town—the latter on South African species.

Economic Importance of the Salt-bushes.—The Kew Bulletin for July and August, 1896, contains a chapter on "Sheep-bushes and Salt-bushes" of South Africa and Australia, which shows the rapidly extending culture of these plants in the warmer and dryer parts of the world. It is therein stated that Australia possesses about 112 species of salsolaceæ, belonging to fifteen genera eight of which are peculiar to it. Species of *Atriplex*, *Kochia*, and *Rhagodia* have been tested, or are under trial, in California. Four other genera, *Chenolea*, *Chenopodium*, *Enchylæna, and Sclerolæna*, are said by the late Baron Von Mueller in his "Iconography of the Australian Salsolaceous Plants" to contain species valuable for pasturage. He continues: "The salt-bushes constitute in many wide tracts of our island-continent, the prevailing vegetation, and on this depends, locally, to a large extent the sustenance of herds and flocks. Moreover, this kind of pasture-nutriment has proved so particularly wholesome that the salt-bush country has become among Australian ruralists quite famous, more particularly as salt-bushes will live even through the direst periodical droughts."

Professor F. Turner, of New South Wales, the botanist of the Agricultural Department, says in his monograph on the "Forage Plants of Australia:" "Once the salt-bushes are established, they will continue to grow under the most adverse circumstances of drought and great heat." He adds that when sheep are pastured where salt-bush is grown, "fluke and other allied ailments are almost unknown," and that horses subject to swamp cancer, on the coast-lands, lose this disease when turned into salt-bush pasture.

Interesting testimony regarding the value of salt-bushes was recently furnished by Mr. Stitt, one of the managers of the famous Tejon Rancho in Kern County, to the effect that on the famous Liverpool Plains of Australia beef-cattle are given six weeks' range on salt-bushes and the true "myall" *(Acacia pendula)*. They are then driven six hundred miles to market and arrive in magnificent condition, furnishing beef of the first quality. While the value of the acacia in this relation is certainly considerable, the best food constituents come from the salt-bushes. Cattle and sheep in Australia also browse freely on leaves of *Acacia aneura*, *A. doratoxylon*, *A. salicina*, and *A. homalophylla*, which are often termed "myalls." The wool produced by acacia forage alone is stated by Mr. Maiden, Director of the Sydney Botanic Garden, to be of less than average quality.

Cause of High Quality of Australian Wools.—All the leading Australian authorities hold that it is the salt-bushes which give an especial value to the famous wools of that country. They assert that the rapid destruction of native salt-bushes, now so painfully apparent in Australia, is certain to materially lessen the market value of Australian wool. This was stated as a fact in the report of a Royal Commission, and has been printed in many Colonial documents. Salt-bushes afford green feed at a season when other plants are dry, and thus maintain the strength and uniformity of the wool-fibre.

Professor Turner remarks: "The high price of Australian wools is solely on the account of our superior indigenous forage plants." Australians are now making every endeavor to restore these pastures by rest and re-seeding.

Some of the Desirable Salt-Bushes.

Baron Von Mueller, in his "Select Extra-Tropical Plants," recommends some twelve species of atriplex, three chenopodiums, three kochias, and five rhagodias, nearly all Australian.

Atriplex cinerea.—This species, a native of the coast region of Australia, is a rather tall and bulky salt-bush, recommended as supplying good cattle-fodder. It has not been introduced into California. Seeds obtained under this name proved to be *A. halimoides.*

Atriplex crystallina.—This species belongs to southeastern Australia and Tasmania. It grows on the brink of the ocean, exposed to salt spray. Though not yet introduced into California, it seems desirable on account of its possible usefulness on the sand dunes and salt marshes. *Atriplex semibaccata* shows distinct limitations in this direction.

Atriplex halimoides.—This species belongs to the extremely dry deserts of central Australia, is one of the best of the dwarf, shrubby species, and is easily raised from seed. It was introduced into South Africa in 1886 by the receipt of six seeds from Australia. Two seeds germinated, one of which afterwards died; the other, as reported in the "Agricultural Journal" of Cape Colony, became the mother plant of all the halimoides found in South Africa. Thousands of acres appear to have been sown with this atriplex since that date. In California this species promises to be very useful and is worthy of more extended trials. It has been freely distributed for several years. The seed should always be covered a quarter to half an inch deep. It is usually sown in its light, fibrous husk. About 20,000 fertile seeds generally occur in a pound.

Plate 5.—Atriplex halimoides.

Atriplex leptocarpa.—This species, a native of East Australia, is one of the trailing herbs which somewhat resemble in its growth the well-known semibaccata. It will stand much drought, and produces seed in abundance. This species was introduced into California in 1891, has been tested in many places, and is widely distributed. It promises to be a valuable plant, and possibly will do better near the coast than the semibaccata. It does not seem to do well on the hardpan lands. There are about ten thousand seeds to the pound.

Plate 6.—ATRIPLEX LEPTOCARPA.

Atriplex Muelleri.—This is a native of the interior of Australia, sometimes reaching the sea coast. Cattle and sheep are said to prefer it to most other species. It has not yet been tested in California.

Atriplex nummularia.—This is one of the tallest of the shrubby atriplexes, sometimes reaching a height of from six to ten feet. It has attracted more attention, except in California, than any other Australian species. Live stock are reported to be extremely fond of it, and its drought-enduring qualities are remarkable. Professor Turner writes, "It stands the hot winds of our arid central plain (Australia) with little check upon its growth." About 1880, this plant was intro-

Plate 7.—ATRIPLEX NUMMULARIA.

duced on the famous alkali plain of India, especially Oudh and the Upper Punjab. Its resistance to alkali was satisfactory, but after ten years' trial, it was found that the excessive damp of the hot, rainy months often destroyed the plants, and its growth was abandoned.

The species has done extremely well in South Africa and, like halimoides, is grown there on a large scale. This is one of the first salt-bushes introduced into California, and hopes of its naturalization were long entertained, but it is dicœcious, and has never made fertile seed here, nor is it practicable to root cuttings cheaply enough to compete with the self-seeding species. Seeds obtained from Australia have twice failed to germinate. The forage value of nummularia is evident, but it has not yet shown its adaptability to California. It seeds freely and volunteers readily in Australia and South Africa, so that further tests in California are desirable.

Atriplex semibaccata.—A perennial herb, "considered among the best of the salt-bush country," Pronounced by W. Farrer as wonderful for its productiveness and drought-resisting power. Stems in its native district, Queensland, are said to spread one or two feet. Australians who have visited California say that average plants of semibaccata grown on alkali land in bulk surpass three-fold the best plants seen in Australia. In California the low spreading mass of a single plant sometimes reaches a diameter of twelve feet on alkali soil. This species protects its fallen seeds, and subsequent seedlings, by a light shelter of fallen leaves, which seems to be one secret of its unusual productive powers. Several reports that it grew well near the tide-line along the shore of San Francisco Bay were found to be erroneous. The best showing occurred near Mowry's Station, Alameda County, where a fine field of salt-bush stands about four feet above brackish water, and exposed to the sweep of the sea-wind. Mr. Shaw, of Warm Springs, reported an entire failure with semibaccata on unreclaimed salt-marsh islands. Semibaccata, as well as halimoides, leptocarpa, and vesicaria, have been extensively distributed from the California Station, not only in the United States, but also in Mexico, Guatamala, the Argentine Republic, etc. A letter received, in March, 1899, from President Rocca of the Argentine Republic stated that the plant was entirely successful there. The California Station has agreed to furnish seed of semibaccata, and two other species, to the Department of Agriculture at Washington for still wider distribution during the coming season.

Atriplex spongiosa, *A. stipulata*, *A. angulata*, and *A. velutinella* are said to be valuable dwarf and shrubby species. *A. Campanulata*, the "small salt-bush," is "highly appreciated by stock." A new species *A. Kochiana*, was lately named and described by J. H. Maiden (Treasurer, Royal Society, South Australia). It is allied to *A. vesicaria*, and is a fine large-leaved species, of economic value. None of the species mentioned in this paragraph have yet been tested in California, as seed obtained failed to germinate. Salt-bush seed often arrives in a moldy condition, having been gathered when too green, or wet with dew.

Atriplex vesicaria.—A very interesting species much resembling halimoides but seemingly more easily reproduced from seed and bearing heavier seed crops. As with most other salt-bushes, the spongy or sometimes pulpy seed-envelopes are as nutritious as any other part of the plant. Accordingly to Von Mueller, vesicaria is one of the most fattening and most relished of all the dwarf pasture salt-bushes, holding out in the utmost extremes of drought and not

scorched even by sirocco-like blasts. Splendid wool is produced in regions where vesicaria and halimoides almost monopolize the ground. This seems to be one of the most promising of the dwarf, upright species of recent introduction into California. It does not seem to exceed two feet in height. Vesicaria should be extensively tested on the Mojave and Colorado deserts. It has been planted on a large scale in the south of France. The seed should be lightly covered.

Chenopodium auricomum, and *C. nitraraceum* are tall salt-bushes of Australia, not yet introduced into California.

Kochia eriantha, of Australia, withstands a summer temperature of 120° Fahr., and yields excellent sheep pasture. *K. villosa*, also of Australia is a dwarf shrub whose roots penetrate the arid soil to a depth of eighteen feet or more. It is a good forage plant in its native country. *K. Aphyla* and *K. pyramidata*, stand much drought, but are coarse and woody. Some of the Kochias have been tried in California but not, as yet, with much success. The growth of the plants appears to be quite slow here.

Rhagodia Billardieri is said to be an important plant for binding sea sands. It endures much salt and is browsed upon by cattle and sheep. It has not yet been tested in California.

Rhagodia nutans is a small-leaved, trailing fodder herb, thriving on alkali land and considered useful for forage. *R. linifolia* is another small species of similar habit. The former species is being tested at the California Station and sub-stations. Its brilliant berries are attractive, but do not seem to have as much food-value as the flat, pulpy seeds of *Atriplex semibaccata*.

The most striking rhagodia is *R. spinescens inermis*, see Plate 1, page 2, a large, tall, and shrubby species sometimes reaching a height of five feet. This is a browsing, not a fodder plant, and so far as tested by the station does not offer any especial advantages. *R. parabolica*, the "old man salt-bush" of Queensland, has not been introduced. *A. halimoides* has been sent to California several times under the name of "old man." Professor J. H. Maiden, in his "Useful Native Plants of Australia," applies the term "old man salt-bush" to *atriplex nummularia*, which seems to be authoritative.

PACIFIC COAST SALSOLACEÆ.

The native West-American plants of this order include many weeds and a few of recognized food-value. The herbaceous species abound near the sea coast, or on alkali lands; the shrubby species belong more to the desert regions. Professor E. L. Greene, in his "Flora Franciscana," describes fourteen atriplexes, mostly annuals, found in middle California. The botanists of the Death Valley Expedition sent out by the U. S. Department of Agriculture, in 1891, listed twenty-nine native plants of this order, twelve of which were atriplexes. The botanical work of this notable expedition began at San Bernardino and covered large portions of the Mojave Desert, Antelope Valley, the upper San Joaquin south of Visalia, Owens River Valley, the Panamint and Armagosa regions, the southern Sierras, and part of southwestern Nevada.

Much of this extensive region is a typical salt-bush country of light rainfall and extreme summer heat. The yearly rainfall in Death Valley averages about five inches, while a maximum temperature of 122° Fahr. was five times recorded in 1891. In such a region grow the shrubby atriplexes of the desert, locally known as "greasewoods," which term is applied to *A. canescens*, *A. confertifolia*, *A. hymenelytra*, *A. polycarpa*, *A. Parryi*, and possibly others.

A. canescens, a shrub often eight or ten feet high, is found on suitable locations in California, Nevada, Arizona, New Mexico, and as far east as the Missouri. Cattle are said to become fat upon it, but it is also reported to give a bad taste to the milk. This species and *A. confertifolia* are described as useful forage plants by Jared G. Smith, in Bulletin 2, Division of Agrostology, Department of Agriculture.

A. confertifolia is one of the most distinctive and abundant of the desert bushes on heavy alkali soils, from Dakota south. It appears to furnish a fair amount of winter forage, and grows well on alkali lands. J. Burtt Davy, in his "Notes on the Flora of Honey Lake Valley," California (*Erythea*, January, 1898), states that this atriplex "occupies large areas almost exclusively" on the intermediate alkali lands half way between the lake-shore and the foothills. It forms a bush of about two feet in height, called "white sage" in some districts. This species is elsewhere known as "gray-green sage." The true desert sages are Artemesias.

A. Torreyi, a tall shrub said to be browsed on by cattle, grows in many places in California from Truckee south, and in the upper San Joaquin Valley.

Some annual atriplexes, such as *A. argentea* and *A. hastata*, are described as useful by Thomas A. Williams in his "Forage Plants of the Dakotas" (Bulletin 6, Division of Agrostology, Department of Agriculture), but they are considered of little value in California.

Many other allied species belonging to this useful family are widely distributed on the Pacific Coast. One of these, *Grayia spinosa*, was found by Mr. Davy both in Antelope Valley, Kern County, California, and in Honey Lake Valley, where it is locally known as "rabbit brush" and "buckwheat sage." Its habit of growth is thorny, as its name indicates, but it is considered a valuable winter-forage plant for sheep and cattle. The seeds are especially useful. The Death Valley Expedition found that it occupies a narrow, well-defined belt in the desert regions.

Eurotia lanata is another shrubby perennial locally called "white sage." It is also termed "winter fat" by stockman in Nevada, California, and the Dakotas. Mr. Davy found that it was much prized as a winter forage plant in Lassen County, and parts of Kern County, California. Thomas A. Williams, in Bulletin 6, of the Division of Agrostology ("Grasses and Fodder Plants of the Dakotas"), illustrates and describes this plant which does well on the "dry alkali" lands of Dakota. In Bulletin 5, of the same division, it is listed from Montana as a "valuable winter forage plant, especially for sheep," and is given the local name of "sweet sage" as well as "winter fat." Professor Greene says that it is "a common forage shrub of the Great Basin and Rocky Mountain Region."

The large class of Kochias, several of which have been introduced from Australia, is represented in the upper San Joaquin around Bakersfield, and more abundantly across the Tehachapi and in Antelope Valley, by *Kochia Californica*, a species sometimes used for fodder, and growing in strong alkali soils. On the alkali soils of Lassen County, *K. Americana* takes its place. This species extends east to Wyoming and south to Arizona.

The native American salt-bushes adapted to alkali soils are excellently described by Professor Jared G. Smith, Assistant Agrostologist, in the Year Book of the Department of Agriculture for 1898 (pp. 535–550), which appears while this bulletin is being printed.

Summary of Results.

This bulletin shows that the California station has been experimenting with salt-bushes for eighteen years; that the tests of some species have extended over the greater part of the State, and that *Atriplex semibaccata* is the most generally useful species of all that have been planted, although others are worthy of cultivation. It shows that semibaccata grows on strong alkali soil, furnishing a very large amount of satisfactory pasturage or fodder; that it also thrives on arid non-alkaline uplands, even where wells have to be sunk 200 feet to water, and where the annual rainfall has been less than five inches. While the dwarf, bushy species, such as vesicaria, will also thrive on such uplands, they seem to furnish less pasturage than semibaccata. The salt-bushes are of easy, rapid growth, and are hardy under California conditions. Reported from Australia as enduring 14° Fahr., without injury, some of the American tests would indicate that semibaccata will stand considerably more cold than this. The tolerance of brackish ground-water, and the extreme northern limits of growth are still undetermined.

The West-American Species.—Although California, in common with other regions west of the Mississippi Valley, possesses native salt-bushes and other salsolaceae of more or less economic usefulness as browsing plants, not one of them gives promise of being worth cultivation. Their yield of fodder per acre seems to be much less than that of the tall Australian species, and from every practical point of view, except possibly that of hardiness, they are inferior to the tender-stemmed, hay-producing *A. semibaccata*. Baron Von Mueller, in his writings upon fodder plants, often expressed a belief that some of the California and other desert species of America were worthy of introduction into Australia. So far, however, as the investigation of this Station has proceeeded, through more than one expedition sent out to study the native vegetation of alkali tracts, no native salt-bush is worthy of comparison with *A. semibaccata* in either quantity or quality of the product.

Natural limitations.—It is seldom that a plant shows as much adaptation to differing circumstances as does *Atriplex semibaccata*, but it cannot endure too heavy summer rains, nor the moist atmosphere of many warm countries. Within its own realm, it is unsurpassed among the gifts of nature to the deserts and the alkali wastes which cover so large a part of the earth's surface.

COMPOSITION AND FOOD-VALUE OF THE SALT-BUSHES.

By M. E. Jaffa.

The lesson of the past dry season has taught stockmen, dairymen, and animal feeders in general the value of such drought-resisting plants as the Australian salt-bushes, prominent among which is the *Atriplex semibaccata*, the only one which has received any extended attention in this State. Its habits and propagation have been discussed in previous pages of this Bulletin.

These salt-bushes have a two-fold value in that they are not only valuable forage plants but can be cultivated in soils containing alkali beyond the limits of tolerance for any other plant of similar food-value.

Food-Value of the Various Salt-Bushes.

Chemical investigation of the plant grown at Tulare and Paso Robles gave, respectively, the results shown below. Analysis of *A. campanulata* and *A. nummularia*, made by Professor W. A. Dixon, New South Wales, Australia; and those of some typical fodders are, for comparison, inserted in the following table:

Table I.—Showing the Composition of Different Fodders.

Name and Locality.	Percentage Composition.					
	Moisture.	Pure Ash.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Crude Fat.
Green.						
A. semibaccata—Tulare	78.03	4.58	2.75	3.75	10.41	.48
A. semibaccata—Paso Robles	75.00	4.93	3.93	5.58	10.15	.41
A. campanulata—Australia	75.00	5.98	3.06	4.53	10.87	.56
A. nummularia—Australia	75.00	7.82	4.11	1.81	10.71	.55
Average	75.76	5.83	3.46	3.92	10.53	.50
Alfalfa, average for Calif.	75.04	1.80	4.91	6.34	11.09	.86
Snail Clover, average for Calif.	81.25	2.07	2.85	4.66	8.41	.76
Alfileria, average for Calif.	80.00	1.72	2.83	4.72	9.81	.92
Hays.						
A. semibaccata—Tulare	7.05	19.37	11.64	15.88	44.05	2.01
A. semibaccata—Paso Robles	10.00	17.74	14.14	20.18	36.54	1.47
A. campanulata—Australia	10.00	21.53	11.01	16.30	39.13	2.01
A. nummularia—Australia	10.00	28.15	14.79	6.51	38.55	1.98
Average	9.02	21.70	12.89	14.72	39.57	1.87
Alfalfa, average for Calif.	10.95	6.43	17.60	22.63	39.31	3.08
Bur Clover—Petaluma	8.95	5.00	13.65	30.58	38.22	3.60
Oat Hay—Santa Clara	10.38	6.75	8.31	23.85	47.91	2.80
Wheat Hay—Danville	11.67	6.75	6.48	18.72	54.33	1.85
Common Barley Hay—Tulare	6.44	7.15	11.11	22.55	50.37	2.38

The value of the salt-bush will be better appreciated when it is remembered that in the selection of foods the chief nutrient to be considered is the protein or nitrogenous ingredients. It is indispensable to the healthy and vigorous growth of the animal body, and animals which have been deprived of all nitrogenous materials have died in a very short time. That the salt-bushes range high in this most important ingredient, when compared with other foods, will be seen by an examination of Table 1.

This table is exceedingly interesting and pregnant with valuable and material suggestions.

It is specially worthy of mention that while the salt-bushes named in the table differ materially botanically, and are not of equal adaptation, they are all valuable forage plants, and there is very little preference so far as chemical composition is concerned. But much farther experimentation will be required before the same can be said of them physiologically, or with respect to nutritive values.

The choice of the best variety for a special locality would depend on soil adaptation and the results of feeding experiments.

Green Fodders.—An inspection of the figures indicating the protein contents of the different salt-bushes shows that *A. nummularia* is the richest, and *A. semibaccata*, from Tulare, the poorest in this respect. The average, 3.46 per cent., is higher than the figures given for snail clover and alfileria, but is considerably lower than the corresponding rating of alfalfa.

Crude fiber in the salt-bushes is present in much smaller amounts than in any of the other fodders, and since woody fiber is the least digestible of any part of a fodder, this is rather an advantage than otherwise.

A very close agreement is noted in the case of nitrogen-free extract. The average for the salt-bush is 10.50 per cent., while that for the remaining fodders amounts to 9.80 per cent.

The fat percentage is uniformly lower in the salt-bushes, being about five-eighths of that found in the other materials.

Hays.—An examination of the analyses of the air-dried materials shows that the salt-bushes compare very favorably in nutritive value with the other hays mentioned in the table. The average protein content, 12.89, is twice that noted for wheat hay, 50 per cent. more than the figure given for oat hay, and is only exceeded by bur clover and alfalfa. The average percentages of fat and starchy matter in the salt-bushes are less than those found in cereal hays. But in the case of the latter nutrient, the average is almost identical with the figures named for alfalfa and bur clover.

Digestibility.—As before stated, much more experimentation is required before we can definitely assert that these salt-bushes have as high digestive coefficients as alfalfa and the ordinary hays. Feeding experiments are called for in this direction, and in some cases urgently so.

In making up a ration we would assign to the salt-bush hay about the same digestive coefficients as those for oat hay. The digestibility would be greatly increased if the material were cut into small pieces, as it is a well known fact that much more nutriment is derived from a given amount of fodder, more particularly by the horse and other

solipeds, if it is cut up than if fed as harvested. This has been practically proved by many of the large livery stables, both here and abroad.

Feeding.—It is not advisable to feed the salt-bushes alone, particularly in the air-dried state, owing to the high percentage of saline ingredients, and the general uninviting appearance and condition of the salt-bush hay. In cases of emergency, however, sheep and cattle have existed altogether on this material through an entire season.

Mixed vs. Unmixed Foods.—From the large number of favorable reports, it would seem that many of the failures were due mainly to irrational feeding. In some cases animals which had never seen the salt-bush were given quantities of the unmixed material and were expected to eat it with relish. Such a method of procedure is, to say the least, ill-advised. Any alteration in the food should be slow and gradual. It would be most unwise to substitute *A. semibaccata* for a cereal hay. The better plan would be to feed a very small amount of salt-bush with considerable hay; then increase by degrees the quantity of salt-bush and decrease that of cereal hay until the proportions are about equal. If the green salt-bush were used, then the hay should constitute about one-third of the roughage of the ration.

Utilization of Straw.—The value of straw as a diluent is becoming more appreciated every year. A ration compounded from alfalfa and straw is much more rational than one with alfalfa alone. But it must be remembered that straw is dry, fibrous, and unpalatable, and consequently requires a succulent material to be used in conjunction with it. For this reason it is not desirable to feed the salt-bush *hay* with straw. The green, however, could very advantageously be utilized, more particularly if both feeds were cut up and well mixed. By this method the farmer is not only able to use alkali land which has been considered worthless, but can use in conjunction with the crop from this land another material which has been deemed of little feeding value. The economy of this plan is apparent without discussion.

Silage and the Salt-bush.—The silo has come to California and has come to stay; a more valuable acquisition to the dairyman could hardly be imagined.

Silage could be fed profitably with either the green or air-dried salt-bush; in the latter case, the dryness of the salt-bush would be offset by the succulency of the silage. The amount of silage to be fed per day would depend greatly on the animals and the supplementary materials of the ration. But the maximum should not exceed forty pounds, with about the same amount of green salt-bush. The succulency of the fresh salt-bush would be preserved and the digestibility of some of its fibrous parts increased if it were siloed. With some other material a salty relish would thus be imparted to the silage.

Composition of the Ash.

In order to more forcibly present the extremely important point regarding the adaptibility of the *Atriplex semibaccata* to different soils, it is pertinent to discuss the composition of the ash. An inspection of Table I discloses the unusually high percentage (5.82 average) of the ash. When it is stated that the ash percentages of most of the

green fodders do not exceed two, the large amount of mineral matter in the salt-bushes will be more fully appreciated.

The analyses of the ash of the different salt-bushes are given below:

TABLE II.—ANALYSES OF ASH OF DIFFERENT SALT-BUSHES.

	A. semibaccata.		A. campanulata.	A. nummularia.
	California.		Australia.	
	Tulare.	Paso Robles.		
Silica (SiO_2)	16.24*		2.27†	1.12†
Potash (K_2O)	11.42		13.61	15.69
Soda (Na_2O)	35.39		47.80	45.44
Lime (Ca O)	5.79		8.47	8.65
Magnesia (Mg O)	3.23		5.82	6.77
Peroxide of Iron (Fe_2O_3)	1.38		1.83	.64
Alumina (Al_2O_3)	1.95			
Br. Ox. Manganese (Mn_3O_4)	.22			
Phosphoric Acid (P_2O_5)	2.80		3.80	4.11
Sulphuric Acid (SO_3)	2.64		2.62	3.17
Chlorine (Cl)	24.33	24.03	21.56	18.47
Total	105.35		107.78	104.06
Excess of O due to Cl	5.35		7.78	4.06
	100.00		100.00	100.00
Common Salt, per cent., in ash	39.90	39.39	35.36	30.28
Common Salt, per cent., in fresh plant	1.83	1.94	2.11	2.37
Common Salt, per cent., in air-dried plant	7.73	7.43	7.61	8.52

From the above showing, it is noted that the chief constituent of the ash is sodium chlorid or common salt, ranging from 30.28 per cent. in the nummularia to almost 40 in the semibaccata, both from Tulare and Paso Robles. In addition to the sodium chlorid there is from 15 to 25 per cent. of soda otherwise combined. In other words, for every ton of green material, assuming water at 75 per cent., there would be about 100 pounds of mineral matter containing from 30 to 40 pounds of common salt and about 20 pounds of other sodium compounds.

It will be seen that the percentages of potash, lime, and phosphoric acid are higher both in the ash of the *A. campanulata*, and *A. nummularia* than in the *A. semibaccata*. This is probably due in a measure to the fact that the insoluble silica was not reported in the analyses made by Professor Dixon; if that were included in the table then the revised figures would correspond quite closely with the data given for the semibaccata. The amounts of potash, lime, and phosphoric acid are in any case relatively small, thus rendering salt-bush excellent for de-salting or freeing the soil from objectionable sodium compounds.

Fertilizing Value of the Ash.—In the ash from 1 ton of green plant there are about 11 pounds of potash and 3 pounds of phosphoric acid available as plant-food; or, estimating a crop at about 20 tons per acre, we find about 220 of potash and 60 of phosphoric acid. But as potash

* Reprinted from Bulletin 105. † Soluble Silica.

exists in more than sufficient quantities in most of the valley soils of the State, it is only the phosphoric acid that is to be considered here with regard to the fertilizing value of the ash. The advantage that would accrue to the valley soils by the addition of that amount of phosphoric acid would be much more than offset by the large quantity of alkali salts, chief among which would be the "black alkali," or, carbonate of soda, and the common salt accompanying the phosphoric acid.

It was due to the extraordinary amount of sodium compounds in the ash, that the planting of the salt-bush on non-alkaline lands was not deemed feasible. But the results of the investigation of the ash of the sample from Paso Robles proves that there is only a slight difference between the figures for the total ash, and that the percentage of salt in the ash is almost identical with that, noted for the Tulare sample. This somewhat surprising result furnishes several questions for careful consideration among which are:—

How long will a non-alkaline soil supply the salts required for this plant, and do all arid non-alkaline soils contain a considerable quantity of soluble salts? These suggest very pointedly the necessity of further study of the leachings of such soils.

Examinations made by Dr. R. H. Loughridge on some soils of this character from Southern California indicate that they contain about 2,500 pounds of soluble salts per acre in a depth of three feet. The corresponding amount for the Paso Robles soils is about 4,500 pounds per acre in three feet. An ordinary crop of *A. semibaccata* withdraws from the soil about 800 pounds of common salt; but owing to the great penetrative power of the roots of this plant it is not dependent for this mineral matter in the upper layers of the soil only.

In this connection it is interesting to compare the composition of the ash of the salt-bushes with that of some other plants. The following table, reprinted from Bulletin 105, presents these data:—

TABLE III.—SHOWING ASH COMPOSITION OF THE SALT-BUSH AND SOME OTHER PLANTS.

	A. Semibaccata.	*Greasewood, Kern Co.	†Greasewood, New Mex'o.	Alfalfa, Eastern.	Timothy Hay, Eastern.
Silica	‡16.24	11.81	3.00	9.38	35.60
Potash	11.42	18.53	22.06	23.45	28.80
Soda	35.39	39.45	23.89	1.56	2.70
Lime	5.75	1.36	6.52	44.30	9.30
Magnesia	3.25	1.09	1.35	4.68	3.60
Br. Ox. Manganese	.22				
Peroxid Iron and Alumina	3.33	7.06	4.73		
Phosphoric Acid	2.80	3.51	4.12	8.34	10.80
Sulphuric Acid	2.64	4.93	4.33	8.73	3.90
Chlorine	24.33	15.30	8.01	3.12	5.00
Carbonic Acid			23.80		
	105.35	103.04	102.81	100.56	99.70
Less excess of O. due to Cl	5.35	3.25		.68	
Total	100.00	99.79		99.88	
Percentage of Ash in air-dried plant	19.37	12.03		5.89	6.15

* Not the greasewood of Nevada, but the *Allenrolfea occidentalis*.
† From greasewood *Sarcobatus vermiculatus* of New Mexico (New Mexico bulletin 22).
‡ About one-half of the silica is soluble in carbonate of soda solution.

It is thus seen that the ash of the salt-bush approaches more nearly in composition to the ash of the greasewood than to that of either alfalfa or timothy. The percentages of potash and phosphoric acid in the ash of the salt-bush are each less than in any of the other plants.

But although the *percentages* of these two vital ingredients are somewhat low, the actual *amounts* contained in the ash from a single crop of the salt-bush are far in excess of those found for an ordinary crop of hay.

The most striking feature of the salt-bush as compared with the other plants, is the excessive amount of chlorine as compared with that in greasewood, alfalfa, and timothy.

Again, while it is true that the percentages of potash and phosphoric acid are less in the ash of the salt-bush than in that of the other plants, when calculated on the *same amount of ash*, yet the percentage of ash being so much greater in the salt-bush, there will be withdrawn from the soil more potash by a ton of salt-bush than by the same weight of the other cultures. Table V illustrates this point.

TABLE IV. QUANTITIES OF SOIL INGREDIENTS WITHDRAWN BY VARIOUS PLANTS (Air Dried).

	Total Ash, lbs.	Potash, lbs.	Phos Acid, lbs	Lime, lbs.	Nitrogen, lbs.
Salt-bush—In 1,000 lbs.	193.70	21.30	5.93	11.14	18.60
Crop of 10,000 lbs.	1,937.00	213.00	59.30	111.40	186.00
Sugar-beets (fresh)—In 1,000 lbs.	18.93	5.38	1.61	3.11	2.38
Crop of 72,000 lbs.	1,349.72	387.44	116.16	224.08	173.40
Roots of 40,000 lbs.	287.00	152.00	36.00	16.00	60.40
Tops of 32,000 lbs.	1,062.00	235.44	80.16	208.00	113.00
Alfalfa—In 1,000 lbs.	65.00	13.49	6.43	22.86	22.50
Crop of 12,000 lbs.	780.00	161.88	77.16	274.32	270.00
Wheat (whole plant)—In 1,000 lbs.	51.26	9.15	4.13	2.30	8.75
Crop of 5,000 lbs.	256.30	45.75	20.65	11.50	43.75
Timothy Hay—In 1,000 lbs.	61.50	17.71	6.64	5.72	15.40
Crop of 5,000 lbs.	307.50	88.55	33.20	28.60	77.00

The total ash of a crop of salt-bush, as indicated above, is more than three times that contained in one of the timothy, two and a half times that removed by a crop of alfalfa, and about fifty per cent. greater than the figure obtained for sugar-beet (entire), but withdraws between six and seven times as much mineral matter as the beet roots alone.

The amount of potash removed from the soil by a crop of salt-bush is greatly in excess of the quantity withdrawn by alfalfa, or sugar-beets (roots), more than twice that taken by timothy, and nearly four times the amount found in wheat hay. The draft of phosphoric acid upon the soil is greatest in the case of sugar-beets (entire) and least in wheat hay. The amount found in the salt-bush, fifty-nine pounds, is nearly three times that given for wheat hay, one and one-half times that for sugar-beets (roots), but only about three-fourths the weight of phosphoric acid required for a crop of alfalfa. With reference to lime, it seems that a crop of alfalfa carries more of this ingredient than do

all the remaining plants here presented, with the exception of sugar-beets. The highest figure for nitrogen is 270, reported for alfalfa; the salt-bush requiring about two-thirds of this amount.

It therefore appears that while the salt-bush removes an enormous amount of ash, it does not correspondingly draw upon the vital ingredients.

Amount of Alkali Salts removed from the soil by a crop of Salt-bush.—It is of interest to know just how much of the injurious salts of alkali soils are extracted, per acre, by an average crop of salt-bush. As before stated, this plant is grown on some of the worst spots of "black alkali" at Tulare station.

In column I, of Table V, below, are given the amounts, in pounds per acre, of alkali salts in the crude ash of a crop of the salt-bush, estimating the yield at five tons per acre. In column II, the number of pounds of the alkali salts as they occur in the soil; assuming an acre one foot deep to weigh four million pounds; column III expresses the percentage of the total quantity in the soil, which is extracted by the salt-bush:

TABLE V.

	I. Alkali Salts in Crop of Five Tons of Salt-Bush. Pounds per Acre.	II. Alkali Salts in Soil. Pounds per Acre.	III. Percentage of Total Salts Extracted by Salt-Bush.
Sodium Sulphate		26,040.00	
Potassium Sulphate	111.48	4,440.00	2.51
Sodium Chlorid	797.59	19,400.00	4.11
Sodium Carbonate	471.10	20,360.00	2.31
			Average.
Total	1,380.17	70,240.00	1.90
Total Sodium Salts	1,268.69	65,800.00	1.92

From this table it will be noted that sodium carbonate and sodium chlorid, the two most injurious of alkali salts, are removed from the soil in no inconsiderable quantities by a single crop of the salt-bush; and while it would require many years of such cropping to render such a soil, containing nearly one and three-quarters per cent. of alkali salts, fit for other cultures, yet on soils where the percentage of alkali is near the limit of injury, a few crops of the salt-bush would, in all probability, bring it below the danger point.

In addition, therefore, to the advantages referred to in the previous part of this Bulletin, the following points deserve attention:

Soils where the percentages of alkali are near the limit of tolerance can no doubt be sensibly relieved by planting the salt-bush and perminently removing each cutting from the land.

The composition is, aside from the ash, such as to make it an excellent food for stock; it seems to be readily eaten by them.

The question still to be settled is whether the large amount of saline ingredients will be harmless to all kinds of stock; *e.g.*, milch cows. Assuredly no salting will be necessary; and if no purgative effect is noted, no other disadvantage need be apprehended.